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Effect of *Pseudocercospora* Spot Disease Control and Soil Moisture Management on Citrus Production in Teso Region, Uganda

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Pseudocercospora Spot 병 방제와 토양수분 관리가 Uganda Teso 지역의 오렌지 생산에 미치는 효과

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ABSTRACT: Sweet orange (*Citrus srcinensis*) contributes to food and nutrition security and is a source of employment for the rural population in Uganda. Production of citrus in Teso region of Uganda has been mainly affected by *Pseudocercospora* spot disease and long drought conditions. These stresses have reduced citrus production and farm income. This study was focused on the management of *Pseudocercospora* spot disease cause by *P. angolensis* and soil water improving citrus production and farmers' income in Teso, Uganda. Two trial experiments were set up at already established citrus farmers' fields about *Pseudocercospora* spot disease management and soil water management. Different chemicals were applied for *Pseudocercospora* spot disease management as; (1) Carbendazim in alternation with Ridomil, (2) Carbendazim, (3) Copper plus Ridomil, (4) Carbendazim in alternation with Copper, (5) Ridomil, (6) Copper fungicide. Soil and water management (SWM) practices were established on fields of 20 farmers. They included (1) trenches, (2) basins, (3) Basins + cover crop (clover), (4) Trenches + Basins, (5) Trenches + Basin + Cover crop, (6) Trenches + Basins + Manure, and (7) control. Considering disease spread and development on both young and old orange leaves and fruits, Carbendazim was the most effective (>50%) chemical control in all treatments. There was a significant increase of about 734USD/ha in income of farmers following disease control. All SWM practices increased citrus yields. The highest yield of 55t/ha was obtained from treatment combined use of trenches, basins and manure. Increase in farmers' income was observed across all practices except for the control. These results can be utilized by the government and other support agencies such as KOPIA to plan for more support and up scaling to all sweet orange and citrus farmers in Uganda

Key words: Citrus, Pseudocercospora, soil and water management, farmer income

INTRODUCTION

Sweet orange (*Citrus sinensis*) is one of the most promising enterprises for increasing incomes in rural areas,

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improving nutrition, diversification of exports, provision of raw materials for agro-based industries, and a creation of employment especially for youth (NAADS, 2014; Makorere, 2014; Uganda Investment Authority, 2016). Citrus is characterized by small scale production in Uganda (Kongai *et al*., 2018) and the main cash crop specifically in the Teso sub-region, Eastern Uganda (Reeder *et al*., 2009).

Citrus has gained economic importance in Uganda in recent years. In 1999, citrus production was estimated at 26,000MT per annum (Agona, 2002). This has increased to 400,000MT per annum with an approximate gross profit of USD 2,632 per acre annually (NAADS, 2014). This trend is expected to increase following motivation by the juice processing plant in Soroti district launched in April 13, 2019. The factory has a processing capacity equivalent to 30,000 and 24,000 tons per year of fresh oranges and mangoes, respectively (MFPED, 2019). This is in addition to the growing East Africa regional market. These two market outlets present a great opportunity for increased production and marketing of good quality citrus fruits.

Despite the growing market, commercial citrus production remains a big challenge given the underlying limitations of diseases and drought conditions. These two challenges grossly reduce yields, farmer incomes and contribute to over 50% of the losses (Obonyom and Kumakech, 2018). Citrus diseases and drought significantly affect fruit yield and quality. Upscale climate smart agriculture technologies are needed to help farmers manage citrus disease and conserve soil moisture (Mubiru *et al*., 2017), and thereby promote the citrus industry.

One of the most critical orange diseases in Uganda is *Pseudocercospora* spot disease (Yesuf, 2013), also known as angular leaf spot disease (Ramathan and Odieny, 2017). It causes decline in citrus yields of 50 to 100% and quality (Tennant *et al*., 2009). It also significantly reduces juice content of the fruits, which makes them unsuitable for marketing (Brentu *et al*., 2012). This study focused on trying various chemicals alongside field sanitation to find a lasting solution for farmers.

Teso region characterized by sandy clay and sandy loam soils experiences two rainy seasons and two dry seasons (December to February and June to July) (Mutengu, 2011). In view of the above, citrus production can be only boosted during the rainy seasons. The dry spell affects fields to the extent that several trees dry up (Dorji *et al.*, 2016). It is thus inevitable that to sustain production, avenues of availing water for production during the dry spells are put in place. The soil moisture management study focused on surface runoff water harvesting to fill this gap. The entire research was focused on the management of soil moisture and disease in improving citrus production and farmers' income in Teso, Uganda.

MATERIALS AND METHODS

Disease management

The main disease of citrus in Teso region was identified as *pseudocercospora* spot disease which affects both leaves and fruits. Different chemicals were selected for disease management options were applied. These included (1) Carbendazim in alternation with Ridomil, (2) Carbendazim, (3) Copper plus Ridomil, (4) Carbendazim in alternation with Copper, (5) Ridomil, and (6) Copper fungicide. These were applied in the districts of Kalaki, Soroti, Ngora and Kumi in Teso region. The disease management approach involved the use of Phytosanitation. The sanitation approaches included removal of diseased fruits from the citrus trees and burying them, pruning off diseased twigs and weeding. This was aimed at reducing inoculum in the orchards. There was no control trial set up for the disease trial to avoid creating inoculum for the disease. Spraying was done 8times in a season at an interval of two weeks from onset of rains up to 2 months before harvesting. There was a no spray rest period of one month during flowering to allow pollination to take place.

Data was collected on incidence and severity of *Pseudocercospora.* leaf and fruit spot disease was collected month in pursuit of the effect of the chemicals on disease pressure in the experimental plots. Young leaves refer to the leaves formed after onset of rains which are always followed by flowers. Young fruits refer to all fruits below 2months after formation. Each month, data was collected in a total of 108 datasheets. The data collected was entered in Microsoft excel 2010 and analyzed using GenStat 14th Edition. Disease incidence at the beginning that is before and after implementation was compared to indicate the reduction in disease. The results were presented using tables and bar graphs.

Soil and Water Management

Soil and water management (SWM) practices were established on fields of 20 farmers in Soroti and Ngora districts in Teso region before the start of rains in 2018. They included (1) Trenches, (2) Basins, (3) Basins + Cover crop (clover), (4) Trenches + Basins, (5) Trenches + Basin + Cover crop, (6) Trenches + Basins + Manure and (7) control (no soil management practice applied). Data was collected during the main harvest period which occurs in November to January on crop vigor, yield per tree, costs incurred by farmers during the process of establishing the different SWM practices as well as farm gate prices (Fig. 1). The data collected was entered in Microsoft excel 2010 and analyzed using GenStat 14th Edition The yield data were compared with that

Fig. 1. Pictorial view of soil and water management operational trenches and basins immediately after raining.

from the previous growing season, to allow the researchers assess any benefits observed by farmers accrued from the SWM practices. Costs for construction of basins and planting of cover crops were reported per citrus tree, while those for trenches were reported per unit length of the field over which they were constructed. These costs were then converted on a hectare basis. Similarly, yield was reported per tree while the price of citrus was reported per bag of a variety. These were also converted to a hectare basis.

RESULTS AND DISCUSSION

Effect on disease spread

The deployment of chemical control greatly reduced the spread of *Pseudocercospora* spot disease to leaves and fruits with reduction in disease spread to old leaves ranging between 27 to 58%, whereas fruits, there was a reduction of between 72 and 95% (Fig. 2). Old leaves that had leaves before pesticides treatment and fruits are the major sources of disease inoculum in citrus orchard. Reduced disease spread increases chances of disease control. Therefore proper timing of fungicides spraying (Lanza *et al.*, 2018) that is before emergence of new leaves and after removal of diseases parts reduces spread enhancing effectiveness of the chemical fungicide.

The reduction of disease spread to young leaves and fruits was more significant, this ranging between 57 and 77% on leaves and 75 and 99% on fruits (Fig. 3).

Effect on disease development

Disease development defined by symptom development was not as highly reduced as the incidence. However overall, there was a reduction on symptoms development with deployment of a combination of chemical control and phytosanitation. Symptom severity decreased by 35 to 44% in old leaves and 19 to 44% in old fruits that had fruits before

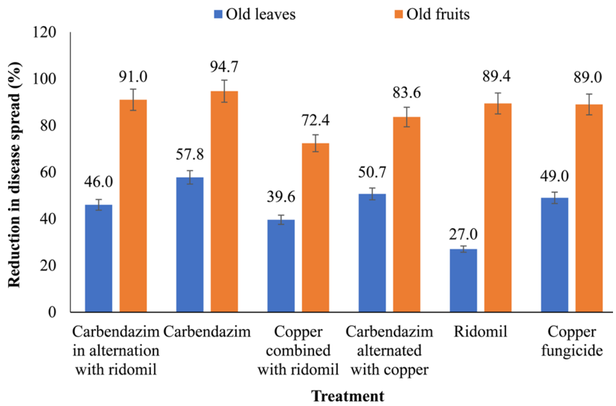

Fig. 2. Effect of management options on spread of *Pseudocercospora* spot disease on old leaves and fruits

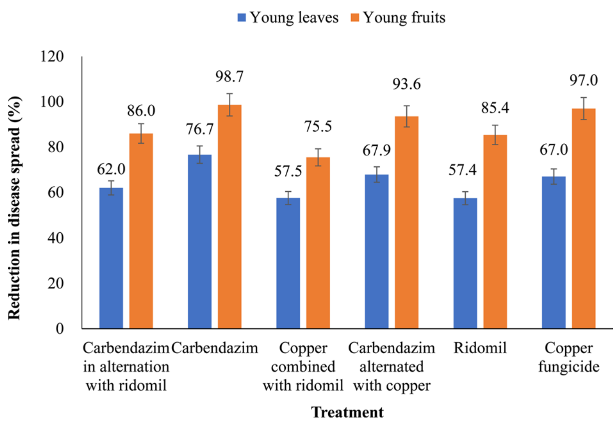

Fig. 3. Effect of management options on spread of *Pseudocercospora* spot disease on young leaves and fruits

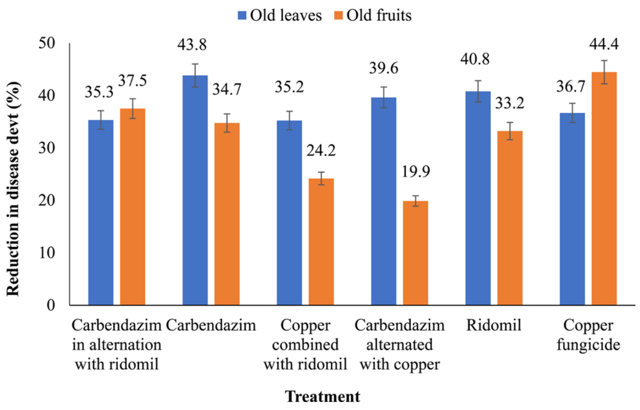

Fig. 4. Effect of management options on *Pseudocercospora* spot disease development on old leaves and fruits

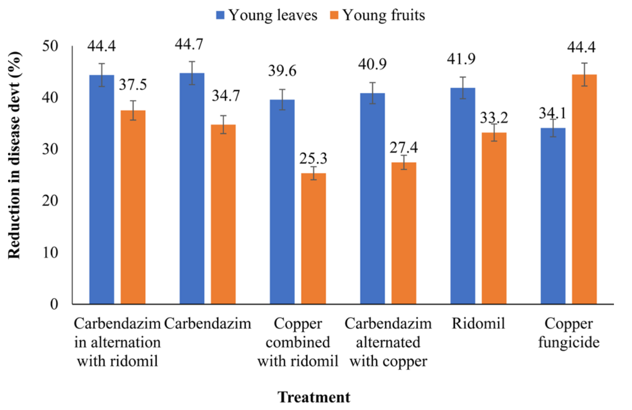

Fig. 5. Effect of management options on *Pseudocercospora* spot disease development on young leaves and fruits

pesticides treatment (Fig. 4). In the previous study, phytosanitation which involved removal of severely diseased fruits and leaves helped reduce inoculum (Yesuf, 2013) increasing chemical effectiveness.

On young leaves and fruits, there were reductions in disease development of 40 to 44% on young leaves and 25 to 44% on young fruits (Fig. 5). This implies that there was less damage to the trees as a result of disease management (Kagorora *et al.*, 2000) ultimately meaning more yields and incomes.

Changes in Yields and Incomes Resulting from Pseudocercospora spot Disease Management

The deployment of citrus disease management options increased the average production per household from 83.3 bags to 129.3 bags (55.2%) while the average incomes per household increased from USD795 to 1390 (74.8%). Thus, the disease management options are greatly increasing household productivity and incomes (Table 1). Carbendazim was the most cost effective disease control (Table 2). However continuous use of one fungicide may results into

Table 1. Effect of *Pseudocercospora* spot disease management by Carbendazim on average household productivity and incomes

	Production in bags (150 kg)		Income (USD)	
Stage in field demonstration	Before Disease Management	After Disease Management	Before Disease Management	After Disease Management
Production/income	83.3±58.08	129.3±58.08	795±98.84	1390±98.84
Change in production/income	55.2%		74.8%	
S.e.d (production/ income)	9.79		206	
P-value $_{(0.05)}$	0.009		0.045	

Table 2. Effect of different *Pseudocercospora* spot disease management options on citrus yield and income

Treatment	Yield/tree (kg)	Yield/ha (kg)	Income/bag (USD)	Income/ha (USD)
Carbendazim alternated with Ridomil	132.2	35,943	12.98	3,528
Carbendazim	137.5	37,382	13.44	3,653
Copper combined with Ridomil	116.5	32,460	11.52	3,201
Carbendazim alternated with Copper	107.0	29,445	10.55	2,897
Ridomil	113.5	30,737	11.05	2,990
Copper fungicide	114.8	31,197	11.23	3,054
P value	0.923	0.897	0.930	0.902
S.e.d	22.62	7,818.6	2.247	772.6

The s.e.d is comparing means of effects of the different chemical treatments on yields and incomes

Table 3. Effect of different soil and water management practices on citrus growth and yield

SWM practice(s)	Wilting	Yield (kg/ha)		Yield increase
	(%)	Before SWM	After SWM	(kg /ha)
Control	36.5	21,963	21,963	0.0
Basins	14.3	30,877	47,506	16,630
Trenches	23.3	25,889	35,185	9,296
Basins + Cover crop	18.6	14,762	23,760	8,998
Trenches + Basins	13.8	17,107	25,079	7,972
Trenches + Basin + Cover crop	10.0	23,033	41,667	18,633
Trenches + Basins + Manure	5.0	33,333	55,556	22,222
Standard Deviation	10.3	12,592.2	14,699.8	7,045

Table 4. Effect of different soil and water management practices on citrus farmers' income (SWM costs indicated)

SWM practice(s)	SWM cost USD/ha	Income (USD/ha)		Benefit from SWM USD/ha
		Before SWM	After SWM	
Control	0.0	2217	2217	0.0
Trenches	69.8	2108	3002	824
Basins	47.0	2517	3905	1341
Trenches + Basins	78.1	3403	4142	433
Basins + cover crop	85.0	1305	2122	732
Trenches + Basin + Cover crop	78.3	1795	3805	1932
Trenches + Basins + Manure	183.3	2791	4566	1593
Standard Deviation	30.1	1720.2	1799.7	712.1

pathogen resistance (Kagorora *et al.*, 2000) therefore alteration with Ridomil is recommended.

Soil and water management practices

Trees in the control plots (no SWM practices at all) had highest percent wilting compared to those where SWM structures were established (Table 3). Plots with trenches, basins and manure combined recorded the lowest percent wilting. For all SWM practices, farmers also reported higher citrus yield compared to what they were getting before. Within one season after establishment of the SWM structures, farmers reported up to 66% increase in citrus fruit yield.

Highest benefits were observed on plots with a combination of Trenches, basins and manure. This is attributed to role of trenches in channeling water into the field and redistribution to the basins. Basins round the plant allow water enough penetration time and control run off (Wright, 2000). Application of manure improves organic matter content which increase water retention capacity of soil and also acts as a source of nutrients to the trees (Abbas and Fares, 2009). This increased its impact compared to single use of sustainable soil and water management practices.

Farmers reported on costs, yield and income following establishment of the different SWM practices (Table 4). Basins were the cheapest to construct, followed by trenches. Combining the two or more practices increased the costs, especially where manure was used. Construction of trenches significantly increased citrus yield but more so with basins. Combining different practices resulted in a corresponding increase in yield, more so with manure.

There was an increase in farmers' income following establishment of all the practices, either singly or in combination. The highest income was reported from plots with trenches, basins and manure combined. On the other hand, the highest increase in income was reported from the plots with trenches, basins and cover crops combined. High increase in income observed from use of cover crops is because the cover crop was provided free of charge to farmers, farmers only incurred a small cost for planting the seedlings on their gardens.

Soil moisture management in the orchard ensures availability of water to the plant all the time. This reduces water stress that normally occurs in the dry season that affects emergence of new leaves, flowering and fruiting (Dorji *et al*., 2016). It in turn translates into high yields and increased income of farmers as well as environmental conservation through soil erosion control.

SUMMARY/CONCLUSION

Pseudocercospora spot disease was reduced on both young and old leaves and fruits by all chemical measures applied. Phyto-sanitation was important in ensuring effectiveness. Carbendazim was the best control measure with over 90% effectiveness which enhanced drastic increase in farm household income.

Combined use of trenches and basins for soil and water conservation resulted in over 25% reduction in citrus wilting during the dry season, compared to the control plots. Combined use of trenches, basins and manure increased citrus yield by 64% over the before soil water management plots with corresponding increase in farmer income.

Considering the severity of the dry spell and *Pseudocercospora* leaf and fruit spot disease levels in Teso region, it is anticipated that through farmer to farmer technology transfer, more citrus farmers will adopt the disease, soil and water management practices demonstrated.

적 요

오렌지는 우간다에서 식량 및 영양 공급과 농촌 일자리 창출에서 매우 중요한 작목이다. 그러나 최근에 우간다 오렌지 주산지 Teso지역 농업인들은 잎과 과일의 반점병뿐만 아니라, 관개시설의 절대적 부족과 기후변화에 의한 가뭄으로 생산량 감소와 폐농하는 사례들이 발생하고 있다. 따라서 본 연구는 우간다 오렌지 생산 농가들의 생산량과 소득을 증가시키기 위하여 효과적인 반점병 및 토양수분 관리 기술을 개발하고자 농가를 대상으로 실증을 실시하였다.

1. 오렌지 반점병 방제에 효과적인 약제를 선발하기 위하여 ridomil, carbendazim, 그리고 cooper 살균제들의 단제, 교호 및 혼합 살포한 결과 Carendazim 단제 사용으로 오렌지 반점병을 방제하였을 때 농가 생산량과 소득은 각각 55.2% 및 74.8% 증가하여 오렌지 나무 대부분 생육단계에서 가장 효과적이었다.

2. 오렌지 과수원 토양수분 관리는 외부에서 과수원으로 연결하는 빗물 유도로(trench)와 오렌지 나무 밑 수반형 빗물 저장시설(basin)을 설치한 다음 가축 배설물(manure)을 함께 처리하였을 때 농가소득이 약 2배나 증가하는 등 가장 효과가 좋았다.

3. 이러한 연구결과를 바탕으로 향후 오렌지 주산지역 농가를 대상으로 시범마을 사업으로 확대 적용할 예정이다.

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